APPENDICES

APPENDIX A

PHOTOPAGES

All the photos on these two photo pages are the original work of the author himself and bears the caption © Danie Esterhuyse. In order to allow more picture area, the captions are presented in two frames on this page, with the actual photos in corresponding boxes on the next two pages.

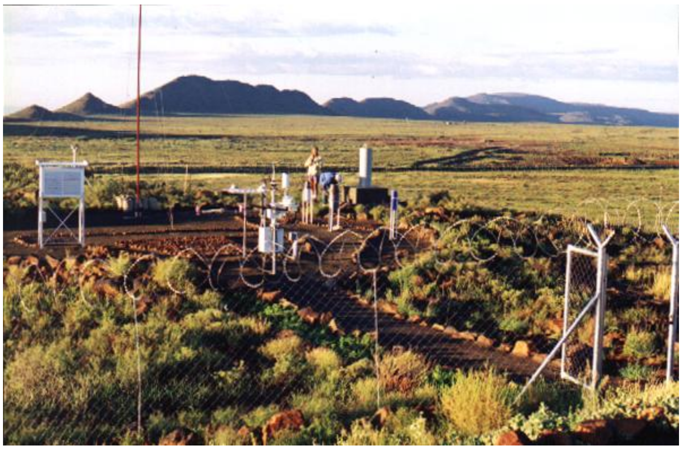
PICTURE CAPTIONS FOR PHOTOPAGE 1

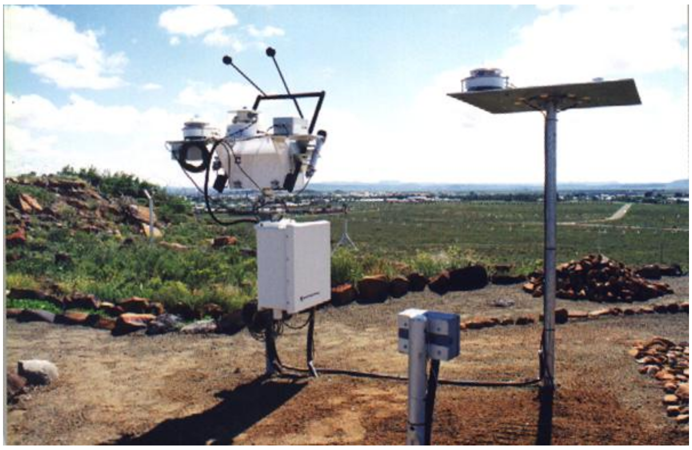
31 December 1997: The author is seen unpacking the first consignment of WMO-sponsored instrumentation at the Forum Building, Pretoria.	20 November 1998: Decisions on site layout was made during a visit. The position of tracker and main instrument box are indicated here.
26 October 1996: Entrance to De Aar from a northern direction, leading to the main street.	13 February 1998: The neat and functional interior of Weather Office De Aar.
28 July 1999: First installation, connecting power plug and serial connection for the solar tracker.	28 July 1999: First installation, digging a trench for burying cable conduits.
25 July 2000: Panoramic view of De Aar, looking northwards from the Weather Office hillock.	

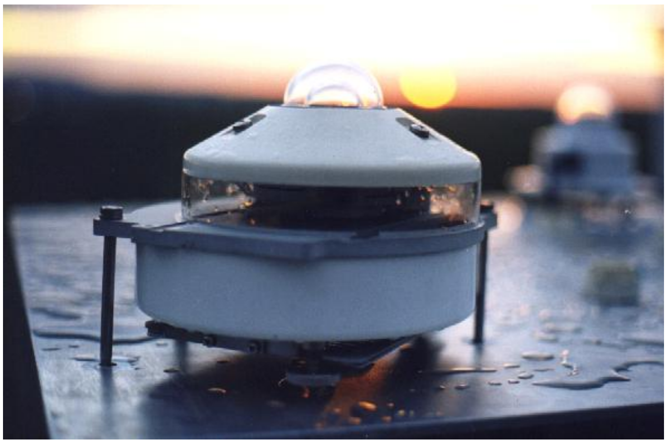
PICTURE CAPTIONS FOR PHOTOPAGE 2

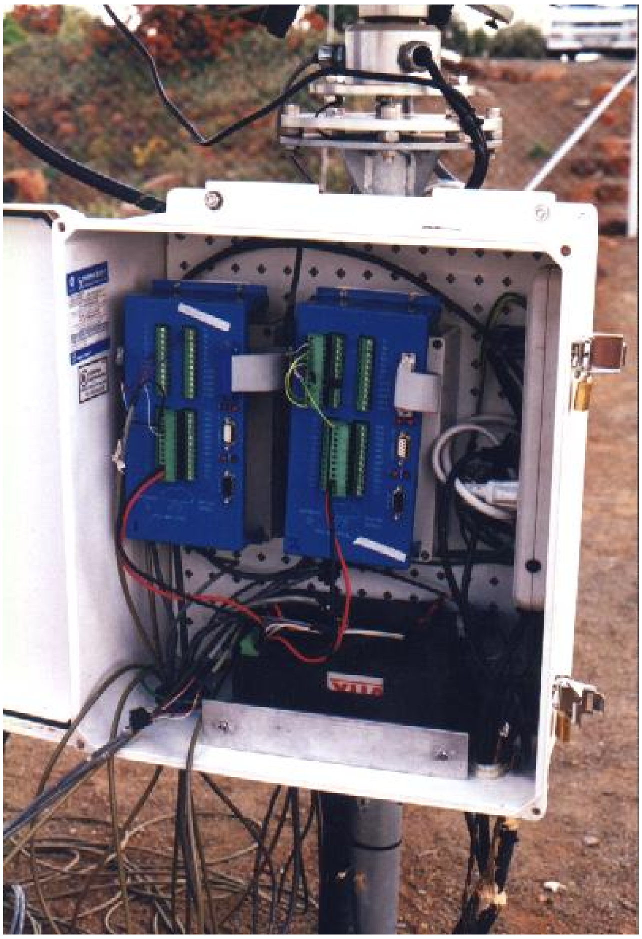
<table>
<tr><td>25 July 2000: Instrument camp setup in early morning light complete with perimeter fence. A GPS station features towards the extreme right.</td><td>30 July 1999: Complete setup: Pyrheliometers, diffusometer and pyrgeometer on tracker, global pyranometer on separate fixed table to the right.</td></tr>
<tr><td>8 March 2001: Global pyranometer at sunrise. Morning dew can be seen on the mounting plate.</td><td rowspan="2">26 July 1999: Lockable instrument box mounted on tracker pole containing all terminals for power (right side) and communication (left side). Main power distribution sockets with transformer for DC power is featured, connected to two dataloggers complete with battery backup and line drivers.</td></tr>
<tr><td>26 September 2001: A cloudless day: six-monthly calibrations are in full swing with Eppley cavity radiometer operated parallel with complete instrumentation on tracker and computer on desk.</td></tr>
<tr><td colspan="2">20 November 1998: Panoramic view of open area to the east of the instrument camp hillock where a 30-metre tower for the measurement of upwelling quantities, can be constructed.</td></tr>
</table>


De Aar









APPENDIX B

STATION-TO-ARCHIVE FILE FORMAT

This annexure reflects the station-to-archive file format in two ways: In Section B.1, the official description of the format required for data files prior to submission is presented, and in Section B.2, a real De Aar file that complied to the conditions and have been accepted in the database.

B.1 FORMAT DESCRIPTION

This is the official description of the BSRN station-to-archive file format as described by WMO (1995). The data file is identified in logical record 0001, by the station identification number, year and month. The dates of change in logical records 0002, 0004, 0005, 0006, 0007, 0008 and 0009 are given by day, hour and minute (dhm) with values ranging from 1...31, 0...23 and 0...59 respectively. The dates of measurement in logical records 0100, 0200, ... are recorded in days and minutes (dm) with values ranging from 1...31 and 0...1439 respectively. This format also applies to quantities measured in hourly intervals.

logical record	line no.	description of field/ format of line	Range of values	Missing code	Format of V1
0001	1	station identification number	Table 4.1		I2
id. of	1	month of measurements	1 - 12		I2
file	1	year of measurement	1992		I4
	1	version of data		- 99	I2
	1	(X,I2,X,I2,X,I4,X,I2)			
	2	id.no.of 1st, 2nd, ... quantity	Table 4.13		I9
		measured (8(X,I9)); missing	Table 4.13		I9
		values -1 to fill up line, as many lines as needed			
0002	1	date when scientist changed (dhm)	0 - 59	-1	3(X,I2)
scien-	2	name of station scientist			A38
tist	2	telephone no. of station scientist			A20
	2	FAX no. of station scientist			A20
	2	(A38,X,A20,X,A20)			
	3	TCP/IP no.		XXX	A15
	3	e-mail address		XXX	A50
	3	(A15,X,A50)			
	4	address of station scientist			A80
	5	date when deputy changed (dhm)	0 - 59	-1	3(X,I2)

	6	name of station deputy			A38
	6	telephone no. of station deputy			A20
	6	FAX no. of station deputy			A20
	6	(A38,X,A20,X,A20)			
	7	TCP/IP no. of deputy		XXX	A15
	7	e-mail address of deputy		XXX	A50
	7	(A15,X,A50)			
	8	address of deputy			A80
0003	1	messages not to be inserted in the BSRN database, as many lines as needed		XXX	A80
0004	1	date when stat. descr. ch. (dhm)	0 - 59	-1	3(X,I2)
station	2	surface type	Table 4.14		I2
descrip-	2	topography type	Table 4.14		I2
tion,	2	(X,I2,X,I2)			
horizon	3	address (A80)			
	4	telephone no. of station		XXX	A20
	4	FAX no. of station		XXX	A20
	4	(A20,X,A20)			
	5	TCP/IP no. of station		XXX	A15
	5	e-mail address of station		XXX	A50
	5	(A15,X,A50)			
	6	latitude [degrees, 0 is South pole, positive is northw.]	0 - 179		F7.3
	6	longitude [degrees, 0 is 180 W, positive is eastwards]	0 - 359		F7.3
	6	altitude [m above sea level]			I4
	6	identification of ``SYNOP'' station		XXXXX	A5
	6	(2(X,F7.3),X,I4,X,A5)			
	7	date when horizon changed (dhm)	0 - 59	-1	3(X,I2)
	8	azimuth [degrees from north clockw.]	0 - 359	-1	I3
		elevation [degrees]	0 - 89	-1	I2
		(11(X,I3,X,I2)); as many lines with 11 pairs to give horizon, last line filled up with -1			
0005	1	date when change occurred (dhm)	0 - 59	-1	3(X,I2)
radio-	1	is radiosonde operating?	Y, N		A1
sonde	1	(3(X,I2),X,A1)			
eqip-	2	manufacturer			A30
ment	2	location			A25
	2	distance from radiation site [km]			I3
	2	time of 1st launch [h UTC]	0 - 23		I2
	2	time of 2nd launch [h UTC]			I2
	2	time of 3rd launch [h UTC]		-1	I2
	2	time of 4th lanch [h UTC]		-1	I2
	2	identification of radiosonde			A5
	2	(A30,X,A25,X,I3,4(X,I2),X,A5)			
	3	remarks about radiosonde		XXX	A80
0006	1	date when change occurred (dhm)	0 - 59	-1	3(X,I2)
ozone m.	1	are ozone measurements operated?	Y, N		A1
equip-	1	(3(X,I2),X,A1)			
ment	2	manufacturer			A30
	2	location			A25
	2	distance from radiation site [km]			I3
	2	identification number of ozone instrument			A5
	2	(A30,X,A25,X,I3,X,I5)			
	3	remarks about ozone measurement		XXX	A80
0007	1	date when change occurred (dhm)	0 - 59	-1	3(X,I2)

station	2	method est. cloud amount (digital proc.)		XXX	A80
history	3	method est. cloud base h. (with instr.)		XXX	A80
	4	method est. cloud liquid water cont.		XXX	A80
	5	method est. cloud aerosol vertical distr.		XXX	A80
	6	method est. water vapor press. v.d. (A80)		XXX	A80
	7	6 flags indicating if the SYNOP	Y,N		A1
		and/or the corresponding quantities of the			
		expanded programme, are measured			
	7	(A1,X,A1,X,A1,X,A1,X,A1,X,A1)			
0008	1	date when change occurred (dhm)	0 - 59	-1	3(X,I2)
radia-	1	is instrument measuring	Y,N		A1
tion	1	(3(X,I2),X,A1)			
instru-	2	manufacturer			A30
ments	2	model			A15
	2	serial number			A18
	2	date of purchase [MM/DD/YY]		XXX	A8
	2	identification number assigned by the WRMC			I5
	2	(A30,X,A15,X,A18,X,A8,X,I5)			
	3	remarks about the radiation instrument		XXX	A80
	4	pyrgeometer body compensation code		-1	I2
	4	pyrgeometer dome compensation code		-1	I2
	4	wavelength of band 1 of spectral i. [micron]		-1.000	F7.3
	4	bandwidth of band 1 of spectral i. [micron]		-1.000	F7.3
	4	wavelength of band 2		-1.000	F7.3
	4	bandwidth of band 2		-1.000	F7.3
	4	wavelength of band 3		-1.000	F7.3
	4	bandwidth of band 3		-1.000	F7.3
	4	max. zenith angle [degree]	0 - 90	-1	I2
	4	min. zenith angle [degree]	0 - 90	-1	I2
		of direct (spectral) instrument			
	4	(2(X,I2),6(X,F7.3),2(X,I2))			
	5	location of calibration			A30
	5	person who calibrated			A40
	5	(A30,X,A40)			
	6	start of calibration period (band 1 of spectr. instr.)			A8
	6	end of ... (both [MM/DD/YY])			A8
	6	number of comparisons (band 1 of spectr.instr.)		-1	I2
	6	mean calibration coefficient (band 1 of spectr. instr.)			F12.4
	6	standard error of cal. coeff.		-1.0000	F12.4
		(band 1 of spectral instrument)			
	6	(A8,X,A8,X,I2,2(X,F12.4))			
	7	start of calibration period band 2 of		XXX	A8
		spectral instrument			
	7	end of ... (both [MM/DD/YY])		XXX	A8
	7	number of comparisons band 2 of spectr. instr.		-1	I2
	7	mean calibration coefficient band 2 of		-1.0000	F12.4
		spectral instrument			
	7	standard error of cal. coeff. band 2 of		-1.0000	F12.4
		spectral instrument			
	7	(A8,X,A8,X,I2,2(X,F12.4))			
	8	start of calibration period band 3 of		XXX	A8
		spectral instrument			
	8	end of ... (both [MM/DD/YY])		XXX	A8
	8	number of comparisons band 3 of spectr. instr.		-1	I2
	8	mean calibration coefficient band 3 of		-1.0000	F12.4
		spectral instrument			
	8	standard error of cal. coeff. band 3 of		-1.0000	F12.4
		spectral instrument			
	8	(A8,X,A8,X,I2,2(X,F12.4))			
	9	remarks on calibration,		XXX	A80

```
                 e.g. units of calibration coefficients
        10       remarks on calibration (continued)              XXX      A80
        11       date when change occurred              0 - 59    -1      3(X,I2)
        11       ...

                 Every radiation instr. at the station is described by
                 10 lines in the format given above (radiation subrecord)

0009     1       date when change occurred (dhm.)       0 - 59    -1      3(X,I2)
assign-  1       id. no. of radiation quantity          Table 4.14        I9
ment of           measured
radia-   1       id. no. of instrument which measured quantity            I5
tion     1       no. of band (for spectral instruments)           -1      I2
quanti-  1       (3(X,I2),X,I9,X,I5,X,I2)
ties to  2       date when change occurred (dhm.)       0 - 59    -1      I2
instru-  2       ...
ments            as many lines to list all quantities together with
                 the instruments; e.g.,
                 ...

                   1  0  0       101 21013  1
                   1  0  0       102 21013  2
                   1  0  0       103 21013  3
                   1  0  0         3 21005 -1
                   1  0  0         4 21006 -1
                  15  0  0         3 21007 -1
                 ...
                 The above lines mean that
                         (i)     the shortwave spectral fluxes at bands 1, 2 and
                                 3 are measured with instrument 21013, bands
                                 1,2,3
                         (ii)    the direct radiation is measured with
                                 instrument 21005 from the 1st day of the month
                                 until the 14th day of the month, with instrument
                                 21007 since the 15th day of the month, and
                         (iii)   the diffuse radiation is measured with
                                 instrument 21006.

                 Legal quantity id. nos. are listed in relation  measvar, legal
                 instrument id. nos. are assigned to the instruments at theBSRN
                 stations by the WRMC. If an instrument measures more than one
                 quantity, lines with the same instrument id. no. and the same
                 date, but with different quantity id. nos. are repeated.
                 However it is not allowed to repeat lines with the same date
                 and the same quantity id. no. As a consequence, the following
                 two lines are illegal, as
                         (i)   quantity id. no. 1 is not in relation measvar,
                               but in relation calcvar, and
                         (ii)  there is more than 1 line with the same time and
                               quantity id. no.
                  < 1  0  0         1 21005  -1   not allowed >
                  < 1  0  0         1 21006  -1   not allowed >
                 Thus calculated quantities are calculated at the WRMC,
                 (Sect. 4.1).

0100     1       date [day]                             1 - 31            I2
basic    1       time [minute]                          0 - 1439          I4
meas.    1       global 2 (mean, std. dev., min., max.:
                 columns 12 - 31)                                -999 or  I4 or
         1       direct (mean, std. dev., min., max.:            -99.9    F5.1
                 columns 35 - 54)
```

	2	diffuse (mean, std. dev., min., max.: columns 12-31)		
	2	downward longwave radiation (mean, std. dev., min., max.: columns 35 - 54)		
	2	air temperature at downw. longw. instr. height	-99.9	F5.1
	2	relative humidity at ...	-99.9	F5.1
	2	pressure at ...	-999	I4
		(X,I2,X,I4,2(3X,I4,X,F5.1,X,I4,X,I4),/ 8X,2(3X,I4,X,F5.1,X,I4,X,I4),4X,F5.1,X,F5.1,X,I4)		
	3	date [day] 1 - 31		I2
	3	...		
		2 lines for each time measured		
0200	1	date [day] 1 - 31		I2
expanded	1	time [minute] 0 - 1439		I4
meas.	1	downw. shortw. spectr. at wavel. 1	-999 or	I4 or
	1	(mean, std. dev., min., max.: columns 12-31)	-99.9	F5.1
	1	... at wavel. 2 (mean, std. dev., min., max.: col. 35 - 54)		
	1	... at wavel. 3 (mean, std. dev., min., max.: col. 58 - 77)		
		(X,I2,X,I4,3(3X,I4,X,F5.1,X,I4,X,I4))		
	2	...		
		1 line for each time measured		
0300	1	date [day] 1 - 31		I2
other	1	time [minute] 0 - 1439		I4
meas.	1	upward shortwave reflected	-999 or	I4 or
in		(mean, std. dev., min., max.: columns 12-31)	-99.9	F5.1
minutes	1	upward longwave		
interv.		(mean, std. dev., min., max.: columns 35-54)		
	1	net radiation (net radiometer)		
		(mean, std. dev., min., max.: columns 58-77)		
	1	(X,I2,X,I4,3(3X,I4,X,F5.1,X,I4,X,I4)		
	2	...		
		1 line for each time measured		
0400	1	date [day] 1 - 31		I2
special	1	time [minute] 0 - 1439		I4
spectral	1	downw. shortw. spectr. at wavel. 4	-999 or	I4 or
meas.	1	(mean, std. dev., min., max.: columns 12-31)	-99.9	F5.1
	1	... at wavel. 5 (mean, std. dev., min., max.: col. 35 - 54)		
	1	... at wavel. 6 (mean, std. dev., min., max.: col. 58 - 77)		
	2	... at wavel. 7 (mean, std. dev., min., max.: col. 12 - 31)		
	2	... at wavel. 8 (mean, std. dev., min., max.: col. 35 - 54)		
	2	... at wavel. 9 (mean, std. dev., min., max.: col. 58 - 77)		
	3	... at wavel. 10 (mean, std. dev., min., max.: col. 12 - 31)		
	3	... at wavel. 11 (mean, std. dev., min., max.: col. 35 - 54)		
	3	... at wavel. 12 (mean, std. dev., min., max.: col. 58 - 77)		
		(X,I2,X,I4,3(3X,I4,X,F5.1,X,I4,X,I4)/ 2(8X,3(3X,I4,X,F5.1,X,I4,X,I4)/))		
	4	...		
		3 lines for each time measured		
0500	1	date [day] 1 - 31		I2
UV	1	time [minute] 0 - 1439		I4
meas.	1	uv-a global (mean, std. dev., min., max.: columns 10 - 32)	-99.9	F5.1
	1	uv-b direct (mean, std. dev., min., max.: columns 34 - 56)		
	2	uv-b global (mean, std. dev., min., max.: columns 10 - 32)		
	2	uv-b diffuse (mean, std. dev., min., max.:		

		columns 34 - 56)			
	2	uv-b upward reflected (mean, std. dev., min., max.:			
		columns 58 - 80)			
		(X,I2,X,I4,4(X,F5.1),4(X,F5.1)/			
		8X,4(X,F5.1),4(X,F5.1),4(X,F5.1)			
	4	date [day]	1 - 31		I2
	4	...			
		2 lines for each time measured			
1000	1	YYGG9 IIiii Nddff 1SnTTT 2SnTdTdTd 3P0P0P0 4PPPP			A80
surface		7wwW1W1 8NhClCmCh 333 8NsChshsh 8NsChshsh 8NsChshsh			
SYNOP		as many lines as needed in format (A80)			
1100	1	date [day]	1 - 31		I2
radio-	1	time [minute]	0 - 1439		I4
sonde	1	observation number			I4
meas. in	1	pressure at level		-999	I4
launch	1	height at level			I5
interv.	1	temperature		-99.9	F5.1
	1	dew point		-999.9	F6.1
	1	wind direction, azimuth	0 - 359	-99	I3
	1	wind speed		-99	I3
	1	ozone concentration		-9.9	F4.1
	1	(X,I2,X,I4,3X,I4,X,I4,X,I5,X,F5.1,X,F6.1,X,I3,X,I3,X,F4.1)			
	2	date [day]	1 - 31		I2
	2	...			
		1 line for each level measured			
1200	1	date [day]	1 - 31		I2
ozone	1	time [minute]	0 - 1439		I4
meas.	1	total ozone amount		-999	I4
in hours	1	(X,I2,X,I4,3X,I4)			
interv.	2	date [day]	1 - 31		I2
	2	...			
		1 line for each time measured			
1300	1	date [day]	1 - 31		I2
expanded	1	time [minute]	0 - 1439		I4
meas.	1	total cloud amount with instrument		-9	I2
in hours	1	cloud base height with instrument in m			
interv.		(no clouds 99999)		-9999	I5
1st part	1	cloud liquid water in mm		-99.9	F5.1
	1	spectral aerosol optical depth at wavelength 1		-9.999	F6.3
	1	spectral aerosol optical depth at wavelength 2		-9.999	F6.3
	1	spectral aerosol optical depth at wavelength 3		-9.999	F6.3
	1	(X,I2,X,I4,3X,I2,X,I5,X,F5.1,2X,3(X,F6.3))			
	2	date [day]	1 - 31		I2
	2	...			
		1 line for each time measured			
1400		expanded measurements second part in hours intervals			
		(water vapour vertical profile by lidar):			
		to be defined later			
1500	1	date [day]	1 - 31		I2
other	1	time [minute]	0 - 1439		I4
measurem.	1	thermal spectral at wavelength 1		-9	I4
in hours	1	thermal spectral at wavelength 2		-9	I4
intervals	1	thermal spectral at wavelength 3		-9	I4
	1	hemispheric solar spectral at wavelength 1		-9	I4
	1	hemispheric solar spectral at wavelength 2		-9	I4

	1	hemispheric solar spectral at wavelength 3		-9	I4
	1	(X,I2,X,I4,2(3X,I4,X,I4,X,I4)			
	2	...			
		1 line for each time measured			

These are two examples for logical records defined for the measurements at the height of 10 and 30 m on the tower of the Payerne (Swiss) station. Such logical records and the corresponding relations in the BSRN database are defined according to the configuration of the instruments at the BSRN stations that perform measurements at heights other than the standard height, i.e., for BSRN stations with a tower. The formats of both records are approximately the same as the format for logical record 100, thus the software for writing the records to the station-to-archive file at Payerne and for reading and inserting the data in the BSRN database at the WRMC is more standardized.

3010	1	date [day]	1 - 31		I2
other	1	time [minute]	0 - 1439		I4
meas.	1	global 2		-999 or	I4 or
at		(mean, std. dev., min., max.: columns 12 - 31)			
10 m	1	shortwave upward		-99.9	F5.1
		(mean, std. dev., min., max.: columns 35 - 54)			
	2	downward longwave radiation			
		(mean, std. dev., min., max.: columns 12 - 31)			
	2	upward longwave radiation			
		(mean, std. dev., min., max.: columns 35 - 54)			
	2	air temperature		-99.9	F5.1
	2	relative humidity		-99.9	F5.1
		(X,I2,X,I4,2(3X,I4,X,F5.1,X,I4,X,I4),/			
		8X,2(3X,I4,X,F5.1,X,I4,X,I4),4X,F5.1,X,F5.1)			
	3	date [day]	1 - 31		I2
	3	...			
		2 lines for each time measured			
3030	1	date [day]	1 - 31		I2
other	1	time [minute]	0 - 1439		I4
meas.	1	global 2		-999 or	I4 or
at		(mean, std. dev., min., max.: columns 12 - 31)			
30 m	1	shortwave upward		-99.9	F5.1
		(mean, std. dev., min., max.: columns 35 - 54)			
	2	downward longwave radiation			
		(mean, std. dev., min., max.: columns 12 - 31)			
	2	upward longwave radiation			
		(mean, std. dev., min., max.: columns 35 - 54)			
	2	air temperature		-99.9	F5.1
	2	relative humidity		-99.9	F5.1
		(X,I2,X,I4,2(3X,I4,X,F5.1,X,I4,X,I4),/			
		8X,2(3X,I4,X,F5.1,X,I4,X,I4),4X,F5.1,X,F5.1)			
	3	date [day]	1 - 31		I2
	3	...			
		2 lines for each time measured			

B.2 A REAL DE AAR DATAFILE

Date: June 2003. Large homogeneous sections omitted. Read in two-column newspaper-style.

```
*C0001
 40  6 2003  1
      2      3      4      5     21     22     23     -1
     -1     -1     -1     -1     -1     -1     -1     -1
*C0002
  1  0  0
Mr. Danie Esterhuyse          +2712 3676053     +2712 3676175
 10.226.  1.187 danie@weathersa.co.za
SAWB,  Private Bag X097,  Pretoria,  0001,  Rep. of South Africa
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Mr. Danie Ferreira            +2753 6311053     +2753 6310628
192.168.145.36  fadyoc@weathersa.co.za
Resp. officer,  De Aar Weath Off,  P.O. Box 270,  De Aar,  7000,  Rep.
of S.A.
*C0003
Take note new IP- address and phone number.
*C0004
  1  0  0
 21  2
De Aar Weather Office  P.O. Box 270  De Aar  7000  Rep. of South
Africa
+2753 6311054     +2753 6310628
192.168.145.37  fady@weathersa.co.za
  59.335 203.993 1287 68536
  1  0  0
0 14   3 14   4 12  14  8  15  2  16  4  18  4  19  1  20  2  21  2  22  1 23
2  24  2  25  1  26  2  27  2  28  1  29  1  30  0  36  0  38  1  40  1 42  1
47  0  48  2  50  1  59  0  61  1  81  1  82  0  87  1  90  1  92  0  93  1  97
1  98  0 100  0 120  0 140  0 141  7 152  7 153  0 160  0 169 0 173  1
174  1 176  0 180  0 182  1 183  0 185  2 187  1 189  3 191  2 192  3
193  2 197  2 199  1 200  1 201  2 202  1 203  0 204  1 205  2 206  1
207  1  208  2 210  1 219  0 224  0 240  0 260  0 280  0 300  0 318  0
319  1 320  1  321  0 322  1 324  0 325  1 326  2 330  2 333  1 337  0
339  1 340  2 341  1  343  1 346  2 347  3 349  2 352  2 353 14 354 14
355 17 356 18 357 18 358 17  359 14  -1 -1  -1 -1  -1 -1  -1 -1  -1 -1  -1
-1  -1 -1  -1 -1  -1 -1  -1 -1
*C0005
  1  0  0 Y
Vaisala DigiCora          De Aar              0 10 -1 -1 -1 RS80
Station  use  old  VLF  radiosondes  -  find  upper-air  winds  by  optic
theodolite
*C0007
  1  0  0
XXX
XXX
XXX
XXX
XXX
Y N N N N N
*C0008
  1  0  0 N
Kipp & Zonen            CH1         970156          12/31/97 40001
Mounted on Sci-Tek 2AP Gear solar tracker
 -1 -1  -1.000  -1.000  -1.000  -1.000  -1.000  -1.000 -1 -1
De Aar                   D. J. Esterhuyse
01/27/03 01/27/03 37      12.6200      0.0410
XXX     XXX     -1     -1.0000     -1.0000
XXX     XXX     -1     -1.0000     -1.0000
Calibration coeff units are in microvolt / Watt / square metre.
Instrument directly compared with AHF cavity nr. 31109
  1  0  0 Y
Kipp & Zonen            CH1         970157          12/31/97 40002
Mounted on Sci-Tek 2AP Gear solar tracker
 -1 -1  -1.000  -1.000  -1.000  -1.000  -1.000  -1.000 -1 -1
De Aar                   D. J. Esterhuyse
01/27/03 01/27/03 37      13.4400      0.0440
XXX     XXX     -1     -1.0000     -1.0000
XXX     XXX     -1     -1.0000     -1.0000
Calibration coeff units are in microvolt / Watt / square metre.
directly compared with AHF cavity nr. 31109
  1  0  0 Y
Kipp & Zonen            CM21         970442          12/31/97 40003
Instrument gets ventilated artificially
 -1 -1  -1.000  -1.000  -1.000  -1.000  -1.000  -1.000 -1 -1
De Aar                   D. J. Esterhuyse
01/27/03 01/27/03 21      19.2700      0.1100
XXX     XXX     -1     -1.0000     -1.0000
XXX     XXX     -1     -1.0000     -1.0000
Calibration coeff units are in microvolt / Watt / square metre.
Alternate sun / shade comparisons with CH1 pyrheliometer.
  1  0  0 Y
Kipp & Zonen            CM21         970443          12/31/97 40004
Instrument gets ventilated artificially
 -1 -1  -1.000  -1.000  -1.000  -1.000  -1.000  -1.000 -1 -1
De Aar                   D. J. Esterhuyse
01/27/03 01/27/03 21      22.4900      0.0270
XXX     XXX     -1     -1.0000     -1.0000
XXX     XXX     -1     -1.0000     -1.0000
Calibration coeff units are in microvolt / Watt / square metre.
Alternate sun / shade comparisons with CH1 pyrheliometer.
  1  0  0 Y
Eppley                  PIR         32200F3         02/28/98 40005
Instrument gets ventilated artificially.
  2  7  -1.000  -1.000  -1.000  -1.000  -1.000  -1.000 -1 -1
Eppley Laboratories          Factory constants
01/08/98 01/08/98 -1       4.2700      -1.0000
XXX     XXX     -1     -1.0000     -1.0000
XXX     XXX     -1     -1.0000     -1.0000
Calibration coeff units are in microvolt / Watt / square metre.
using factory calibrations.
  1  0  0 N
Eppley                  PIR         32201F3         02/28/98 40006
Instrument gets ventilated artificially.
  2  7  -1.000  -1.000  -1.000  -1.000  -1.000  -1.000 -1 -1
Eppley Laboratories          Factory constants
01/08/98 01/08/98 -1       4.1700      -1.0000
XXX     XXX     -1     -1.0000     -1.0000
XXX     XXX     -1     -1.0000     -1.0000
Calibration coeff units are in microvolt / Watt / square metre.
using factory calibrations.
  1  0  0 N
Eppley                  PIR         32202F3         02/28/98 40007
Instrument gets ventilated artificially.
  2  7  -1.000  -1.000  -1.000  -1.000  -1.000  -1.000 -1 -1
Eppley Laboratories          Factory constants
01/08/98 01/08/98 -1       3.8800      -1.0000
XXX     XXX     -1     -1.0000     -1.0000
XXX     XXX     -1     -1.0000     -1.0000
Calibration coeff units are in microvolt / Watt / square metre.
using factory calibrations.
*C0009
  1  0  0        2 40004 -1
  1  0  0        3 40002 -1
  1  0  0        4 40003 -1
  1  0  0        5 40005 -1
*C0100
  1   0     0  0.0    0   0     0  0.0   0   0
          0  0.0   0   0   271  0.5  270  272     9.1  36.1  878
  1   1     0  0.0    0   0     0  0.0   0   0
          0  0.0   0   0   270  0.5  269  271   -99.9 -99.9 -999
  1   2     0  0.0    0   0     0  0.0   0   0
          0  0.0   0   0   270  0.8  269  272   -99.9 -99.9 -999
  1   3     0  0.0    0   0     0  0.0   0   0
          0  0.0   0   0   270  0.4  269  271   -99.9 -99.9 -999
  1   4     0  0.0    0   0     0  0.0   0   0
          0  0.0   0   0   270  0.7  270  271   -99.9 -99.9 -999
  1   5     0  0.0    0   0     0  0.0   0   0
          0  0.0   0   0   271  0.6  270  271     9.1  36.2  878
  1   6     0  0.0    0   0     0  0.0   0   0
          0  0.0   0   0   271  0.5  270  272   -99.9 -99.9 -999
  1   7     0  0.0    0   0     0  0.0   0   0
          0  0.0   0   0   270  0.6  269  271   -99.9 -99.9 -999
  1   8     0  0.0    0   0     0  0.0   0   0
          0  0.0   0   0   270  0.7  269  271   -99.9 -99.9 -999
  1   9     0  0.0    0   0     0  0.0   0   0
          0  0.0   0   0   270  0.6  269  271   -99.9 -99.9 -999
  1  10     0  0.0    0   0     0  0.0   0   0
          0  0.0   0   0   270  0.7  269  271     9.0  36.5  878
  1  11     0  0.0    0   0     0  0.1   0   0
          0  0.0   0   0   270  0.8  268  271   -99.9 -99.9 -999
  1  12     0  0.0    0   0     0  0.0   0   0
          0  0.0   0   0   270  0.8  269  271   -99.9 -99.9 -999
  1  13     0  0.0    0   0     0  0.0   0   0
          0  0.0   0   0   270  0.5  269  271   -99.9 -99.9 -999
```

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```
1 295    0  0.0   0   0     0  0.0   0   0
       0  0.1   0   0   312  0.8  310  313     7.2  44.5  878
1 296    0  0.1   0   0     0  0.1   0   0
       0  0.0   0   0   311  0.5  310  313   -99.9 -99.9 -999
1 297    0  0.0   0   0     0  0.0   0   0
       0  0.1   0   0   311  0.9  309  312   -99.9 -99.9 -999
1 298    0  0.0   0   0     0  0.0   0   0
       0  0.0   0   0   310  1.0  308  311   -99.9 -99.9 -999
1 299    0  0.1   0   0     0  0.0   0   0
       0  0.1   0   0   308  0.8  306  309   -99.9 -99.9 -999
1 300    0  0.1   0   0     0  0.0   0   0
       0  0.1   0   0   306  0.7  305  308     7.3  44.2  878
1 301    0  0.2   0   1     0  0.0   0   0
       0  0.2   0   0   304  0.6  303  306   -99.9 -99.9 -999
1 302    1  0.3   1   1     0  0.0   0   0
       1  0.3   0   1   302  0.4  302  303   -99.9 -99.9 -999
1 303    2  0.2   1   2     0  0.0   0   0
       2  0.2   1   2   300  1.1  298  302   -99.9 -99.9 -999
1 304    2  0.1   2   2     0  0.0   0   0
       2  0.1   2   2   298  1.0  296  299   -99.9 -99.9 -999
1 305    2  0.1   2   2     0  0.0   0   0
       2  0.1   2   2   295  1.0  294  297     7.3  44.4  878
1 306    3  0.1   2   3     0  0.0   0   0
       2  0.0   2   2   293  1.1  291  295   -99.9 -99.9 -999
1 307    3  0.0   3   3     0  0.0   0   0
       2  0.0   2   2   291  0.9  289  292   -99.9 -99.9 -999
1 308    3  0.0   3   3     0  0.0   0   0
       3  0.1   2   3   288  0.7  286  289   -99.9 -99.9 -999
1 309    3  0.1   3   3     0  0.0   0   0
       3  0.1   2   3   286  1.1  285  288   -99.9 -99.9 -999
1 310    3  0.0   3   3     0  0.1   0   0
       3  0.0   3   3   284  0.4  283  285     7.3  44.2  878
1 311    3  0.0   3   3     0  0.1   0   0
       3  0.0   3   3   283  0.7  282  285   -99.9 -99.9 -999
1 312    3  0.1   3   3     0  0.0   0   0
       3  0.0   3   3   282  0.7  281  283   -99.9 -99.9 -999
1 313    3  0.0   3   3     1  0.1   0   1
       3  0.1   3   3   282  0.6  280  282   -99.9 -99.9 -999
1 314    3  0.1   3   4     1  0.1   1   1
       3  0.1   3   3   280  0.6  278  280   -99.9 -99.9 -999
1 315    4  0.1   4   4     1  0.0   1   1
       4  0.1   3   4   278  0.7  277  280     7.3  44.2  878
1 316    4  0.2   4   5     1  0.2   1   2
       4  0.1   4   4   278  0.7  277  279   -99.9 -99.9 -999
1 317    5  0.4   5   6    24 16.7   2  55
       5  0.1   4   5   277  0.7  276  279   -99.9 -99.9 -999
1 318    7  0.5   6   8    91 20.0  56 122
       5  0.1   5   5   277  0.7  276  279   -99.9 -99.9 -999
1 319    8  0.3   8   9   134  4.2 124 140
       5  0.1   5   6   277  0.6  276  278   -99.9 -99.9 -999
```

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```
18 360    78  0.8  77  79   442  2.5  438  446
        27  0.1  26  27   265  0.8  263  266     6.1  49.2  881
18 361    81  0.8  80  82   449  2.4  445  454
        27  0.1  27  27   265  0.5  264  266   -99.9 -99.9 -999
18 362    84  0.8  82  85   457  1.9  453  461
        27  0.1  27  27   265  0.7  264  267   -99.9 -99.9 -999
18 363    86  0.8  85  88   464  2.1  461  468
        28  0.1  27  28   265  0.8  264  266   -99.9 -99.9 -999
18 364    89  0.9  88  90   472  2.3  468  475
        28  0.1  28  28   264  0.7  263  266   -99.9 -99.9 -999
18 365    92  0.8  91  93   479  1.9  475  482
        29  0.2  28  29   265  0.7  264  266     6.3  48.6  881
18 366    95  0.8  93  96   485  1.7  482  487
        29  0.1  29  29   265  0.6  264  266   -99.9 -99.9 -999
18 367    97  0.8  96  99   490  1.9  487  494
        30  0.1  29  30   265  0.8  264  266   -99.9 -99.9 -999
18 368   100  0.8  99 101   497  1.6  494  499
        30  0.1  30  30   265  0.9  264  267   -99.9 -99.9 -999
18 369   103  0.9 101 104   503  1.9  500  506
        30  0.1  30  31   265  0.6  265  267   -99.9 -99.9 -999
18 370   106  0.9 104 107   509  2.1  506  512
        31  0.1  31  31   265  0.8  264  267     6.4  48.1  881
```

```
30 1426    0  0.0   0   0     0  0.0   0   0
       0  0.0   0   0   252  0.6  251  253   -99.9 -99.9 -999
30 1427    0  0.0   0   0     0  0.0   0   0
       0  0.0   0   0   252  0.6  251  253   -99.9 -99.9 -999
30 1428    0  0.0   0   0     0  0.1   0   0
       0  0.0   0   0   252  0.3  251  253   -99.9 -99.9 -999
30 1429    0  0.0   0   0     0  0.1   0   0
       0  0.0   0   0   253  0.3  252  253   -99.9 -99.9 -999
30 1430    0  0.0   0   0     0  0.1   0   0
       0  0.0   0   0   252  0.6  252  254     6.3  31.6  879
30 1431    0  0.0   0   0     0  0.1   0   0
       0  0.0   0   0   253  0.5  252  253   -99.9 -99.9 -999
30 1432    0  0.0   0   0     0  0.0   0   0
       0  0.0   0   0   252  0.7  251  253   -99.9 -99.9 -999
30 1433    0  0.0   0   0     0  0.0   0   0
       0  0.0   0   0   252  0.6  251  253   -99.9 -99.9 -999
30 1434    0  0.0   0   0     0  0.0   0   0
       0  0.0   0   0   252  0.6  251  253   -99.9 -99.9 -999
30 1435    0  0.0   0   0     0  0.0   0   0
       0  0.0   0   0   252  0.6  251  253     6.3  31.5  879
30 1436    0  0.0   0   0     0  0.0   0   0
       0  0.0   0   0   252  0.6  251  253   -99.9 -99.9 -999
30 1437    0  0.0   0   0     0  0.0   0   0
       0  0.0   0   0   252  0.5  252  253   -99.9 -99.9 -999
30 1438    0  0.0   0   0     0  0.0   0   0
       0  0.0   0   0   252  0.6  251  253   -99.9 -99.9 -999
30 1439    0  0.0   0   0     0  0.0   0   0
       0  0.0   0   0   252  0.6  251  253   -99.9 -99.9 -999
```

```
*U1000
01009 68538 /1506 10091 21052 38796 48584 7//// 8////   333 8//// 8////
8////
01019 68538 /1508 10072 21048 38791 48578 7//// 8////   333 8//// 8////
8////
01029 68538 /1510 10066 21045 38789 48576 7//// 8////   333 8//// 8////
8////
01039 68538 21510 10076 21045 38789 48576 7//// 80001   333 8////
8//// 8////
01049 68538 21508 10070 21041 38791 48577 7//// 80001   333 8////
8//// 8////
```

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```
30189 68538 00504 10092 21088 38812 48595 70500 8////   333 8////
8//// 8////
30199 68538 /0406 10093 21087 38811 48593 7//// 8////   333 8//// 8////
8////
30209 68538 /0404 10087 21092 38812 48594 7//// 8////   333 8//// 8////
8////
30219 68538 /0000 10085 21094 38813 48595 7//// 8////   333 8//// 8////
8////
30229 68538 /0404 10089 21091 38811 48593 7//// 8////   333 8//// 8////
8////
30239 68538 /0404 10076 21093 38804 48585 7//// 8////   333 8//// 8////
8////
*C1100
 1  720    1  877  1287  22.2   -2.5 340   6 -9.9
 1  720    2  873  1331  19.2   -3.6 -99 -99 -9.9
 1  720    3  867  1386  18.8   -3.9 -99 -99 -9.9
 1  720    4  861  1444  18.2   -3.8 -99 -99 -9.9
 1  720    5  855  1507  17.5   -3.8 -99 -99 -9.9
 1  720    6  849  1569  16.9   -3.2 -99 -99 -9.9
 1  721    7  843  1627  16.3   -2.7 313  14 -9.9
 1  721    8  838  1683  15.8   -3.1 -99 -99 -9.9
 1  721    9  832  1737  15.3   -3.1 -99 -99 -9.9
 1  721   10  827  1793  14.8   -3.0 -99 -99 -9.9
 1  721   11  821  1852  14.2   -2.7 -99 -99 -9.9
 1  721   12  815  1918  13.6   -2.8 -99 -99 -9.9
 1  722   13  808  1988  13.1   -3.2 309  12 -9.9
 1  722   14  802  2051  12.5   -2.9 -99 -99 -9.9
 1  722   15  796  2117  12.0   -3.4 -99 -99 -9.9
 1  722   16  789  2184  11.5   -4.6 -99 -99 -9.9
 1  722   17  783  2249  11.0   -5.5 -99 -99 -9.9
 1  722   18  777  2316  10.6   -7.1 -99 -99 -9.9
```

(continuing . . .)

```
30  765   271   80 17808 -65.6  -87.1 -99 -99 -9.9
30  765   272   80 17864 -65.4  -86.9 -99 -99 -9.9
30  765   273   79 17919 -65.3  -86.9 -99 -99 -9.9
30  765   274   78 17973 -65.3  -86.9 -99 -99 -9.9
30  765   275   78 18027 -64.4  -86.2 -99 -99 -9.9
30  765   276   77 18077 -63.8  -85.7 -99 -99 -9.9
30  766   277   76 18127 -63.3  -85.3 -99 -99 -9.9
30  766   278   76 18185 -63.1  -85.1 -99 -99 -9.9
30  766   279   75 18244 -62.9  -85.0 -99 -99 -9.9
30  766   280   74 18299 -62.8  -84.9 -99 -99 -9.9
30  766   281   73 18357 -62.8  -84.9 -99 -99 -9.9
30  766   282   73 18415 -62.6  -84.7 -99 -99 -9.9
30  767   283   72 18476 -62.4  -84.6 -99 -99 -9.9
30  767   284   71 18537 -62.5  -84.7 -99 -99 -9.9
30  767   285   71 18597 -62.7  -84.8 -99 -99 -9.9
30  767   286   70 18658 -62.9  -85.0 -99 -99 -9.9
30  767   287   69 18718 -63.1  -86.9 -99 -99 -9.9
30  767   288   69 18781 -63.2  -86.9 -99 -99 -9.9
30  768   289   68 18845 -63.2  -86.9 -99 -99 -9.9
```

APPENDIX C

SPECIFIC DATA FOR A TYPICAL YEAR AT DE AAR

Date	Sun-rise	Sun-set	Solar noon	Day-length	TOA $kJ.m^{-2}$	Date	Sun-rise	Sun-set	Solar noon	Day-length	TOA $kJ.m^{-2}$
01 Jan	05:24	19:30	12:27	14:05	43938	05 Jul	07:21	17:35	12:28	10:13	18423
06 Jan	05:28	19:30	12:29	14:02	43754	10 Jul	07:21	17:37	12:29	10:16	18747
11 Jan	05:32	19:31	12:31	13:58	43490	15 Jul	07:19	17:40	12:29	10:20	19172
16 Jan	05:36	19:30	12:33	13:53	43144	20 Jul	07:17	17:42	12:30	10:24	19693
21 Jan	05:41	19:29	12:35	13:47	42719	25 Jul	07:15	17:45	12:30	10:30	20305
26 Jan	05:45	19:27	12:36	13:41	42213	30 Jul	07:12	17:48	12:30	10:36	21002
31 Jan	05:50	19:24	12:37	13:34	41629	04 Aug	07:08	17:51	12:30	10:43	21778
05 Feb	05:54	19:21	12:38	13:26	40969	09 Aug	07:04	17:54	12:29	10:50	22626
10 Feb	05:59	19:17	12:38	13:18	40235	14 Aug	06:59	17:57	12:28	10:58	23537
15 Feb	06:03	19:12	12:38	13:09	39431	19 Aug	06:54	18:00	12:27	11:06	24504
20 Feb	06:07	19:08	12:37	13:00	38560	24 Aug	06:49	18:03	12:26	11:14	25519
25 Feb	06:11	19:02	12:37	12:51	37629	29 Aug	06:43	18:06	12:25	11:22	26572
02 Mar	06:15	18:57	12:36	12:42	36644	03 Sep	06:37	18:09	12:23	11:31	27655
07 Mar	06:18	18:51	12:35	12:33	35610	08 Sep	06:31	18:12	12:21	11:40	28759
12 Mar	06:22	18:45	12:33	12:23	34536	13 Sep	06:25	18:14	12:20	11:49	29876
17 Mar	06:25	18:39	12:32	12:14	33429	18 Sep	06:18	18:17	12:18	11:58	30997
22 Mar	06:28	18:33	12:31	12:04	32299	23 Sep	06:12	18:20	12:16	12:07	32113
27 Mar	06:31	18:27	12:29	11:55	31153	28 Sep	06:06	18:23	12:14	12:17	33216
01 Apr	06:34	18:21	12:28	11:46	30002	03 Oct	06:00	18:26	12:13	12:26	34298
06 Apr	06:37	18:15	12:26	11:37	28854	08 Oct	05:53	18:29	12:11	12:35	35351
11 Apr	06:41	18:09	12:25	11:28	27720	13 Oct	05:48	18:32	12:10	12:44	36368
16 Apr	06:44	18:03	12:23	11:19	26609	18 Oct	05:42	18:36	12:09	12:53	37342
21 Apr	06:47	17:58	12:22	11:10	25530	23 Oct	05:37	18:39	12:08	13:02	38267
26 Apr	06:50	17:53	12:21	11:02	24493	28 Oct	05:32	18:43	12:07	13:11	39137
01 May	06:53	17:48	12:21	10:54	23507	02 Nov	05:27	18:47	12:07	13:19	39946
06 May	06:57	17:44	12:20	10:47	22581	07 Nov	05:23	18:51	12:07	13:27	40691
11 May	07:00	17:40	12:20	10:40	21723	12 Nov	05:20	18:55	12:08	13:35	41367
16 May	07:03	17:37	12:20	10:33	20940	17 Nov	05:17	19:00	12:08	13:42	41972
21 May	07:06	17:34	12:20	10:27	20241	22 Nov	05:15	19:04	12:10	13:48	42503
26 May	07:09	17:32	12:21	10:22	19631	27 Nov	05:14	19:08	12:11	13:54	42958
31 May	07:12	17:30	12:21	10:18	19116	02 Dec	05:13	19:12	12:13	13:59	43336
05 Jun	07:15	17:29	12:22	10:14	18701	07 Dec	05:13	19:16	12:15	14:02	43637
10 Jun	07:17	17:29	12:23	10:12	18388	12 Dec	05:14	19:20	12:17	14:05	43858
15 Jun	07:19	17:29	12:24	10:10	18180	17 Dec	05:16	19:23	12:20	14:07	44000
20 Jun	07:20	17:30	12:25	10:09	18080	22 Dec	05:18	19:26	12:22	14:07	44062
25 Jun	07:21	17:31	12:26	10:09	18087	27 Dec	05:21	19:28	12:24	14:07	44044
30 Jun	07:22	17:33	12:27	10:10	18202	31 Dec	05:24	19:30	12:27	14:05	43945

APPENDIX D

THE KÖPPEN CLIMATE ZONE CLASSIFICATION

The Köppen climate zone criteria is widely recognized as a tool for classifying regions of the world in climate zones, and was also used as a criterium to denote BSRN geographical climate zone representivity. The classification system was developed in 1928 by the German geographer-meteorologist Wladimir Köppen (1884–1931) based upon and described by dominant types of vegetation found in the respective regions. Although the classifications are mainly driven by climate characteristics, vegetation type also features prominently as depicted in Table D.1.

Five main classes denoted by the capital letters A to E, were originally developed with a sixth, H, added later. Other letters added after the capitals denote sub-divisions per class:

Subtypes for Temperature

- **a** Warmest month above or equal to 22 °C (for C or D climates)
- **b** Warmest month below 22 °C (for C or D climates)
- **c** Less than four months over 10 °C (for C or D climates)
- **d** Same as 'c' but coldest month below -37 °C (for D climates)
- **h** Hot and dry: all months above 0 °C (for B climates)
- **k** Cool and dry: at least one month below 0 C (for B climates)

Subtypes for Precipitation

- **s** Dry season in summer: when 70% or more of annual precipitation falls in winter (for C climates)
- **w** Dry season in winter: when 70% or more of annual precipitation falls in summer (for A, C, or D climates)
- **f** Constantly moist: rainfall consistent throughout the year (for A, C, or D climates)
- **m** Monsoon rain: short dry season, precipitation in driest month < 60 mm and total annual precipitation > 1250 mm, when both 'w' and 'm' subtypes are met, 'm' subtype takes precedence, don't use both subtypes (for A climates)

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[1] *http://www.squ1.com/climate/koppen.html*

Table D.1 *Descriptive properties of the Köppen climate zone classification*

A: Tropical	**B: Dry**	**C: Temperate**	**D: Cold**	**E: Polar**
Average coolest month ≥ 18°C.	*Annual precipitation < 860 mm.*	*Coldest month > 0°C and < 18°C. Warmest month > 10°C.*	*Coldest month < 0°C. Warmest month > 10°C.*	*Tundra: Warmest month < 10°C, Polar: all months < 0°C.*
Af *(Tropical rainforests).* Perpetual precipitation. Monthly temp vary < 3°C. Typical max/min 22°C and 32°C.	**BW** *(Arid)* A true desert climate. It covers 12 % of the Earth's land surface.	**Cfa** *(Humid subtropical)* Hot muggy summers with mainly thunderstorms. Mild winters with precipitation via mid-latitude cyclones. Vegetation deciduous and non-deciduous trees (mangrove, magnolia, cypress, mossy oak trees).	**Dfa** and **Dfb** (*Humid Continental*) – perpetually wet with cool summers, all trees defoliate but needle-leaf.	**ET** (*Tundra*) – no trees, rolling grasslands covered with snow throughout most of the year; at least 1 month of above freezing temperatures. Wide occurrence of permafrost. Vegetation dominated by mosses, lichens, dwarf trees and scattered woody shrubs.
			Ds (*Dry summers)*	
Am (*Tropical monsoon)* Dry season with almost no rain, hot season with more rain than Af.	**BS** *(Steppe)* Dry semiarid grassland climate that covers 14% of the Earth's land surface.	**Csa** ***(****Mediterranean)* Rain primarily during winter via mid-latitude cyclone, with extreme summer aridity. Vegetation oak woodlands, grasslands and chaparral.	**Dfc** (*Subartic*) - associated with the boreal or taiga forests of single stands of trees such as the firs or spruce tree.	
Aw *(Tropical wet and dry-Savannah)* Extended dry winter and only summer rainfall, usually < 1000 mm.		**Cfb** *(Marine west coast)* Humid climate with short dry summer. Heavy precipitation occurs during the mild winters because of continuous presence of mid-latitude cyclone. Vegetation mixed evergreen forests coniferous [cone-bearing] and deciduous [leaves *fall-off*] trees.	**Dw** *(Dry winters)*	**EF** *(Polar ice)* Ice caps that have a surface that is permanently covered with snow and ice since temperatures never exceed freezing.

H *(Highlands)* A climate zone in itself due to the unique climate properties that places of exceptional high altitude, exhibit.

The following map (Figure D.1) reflects how these regions are geographically represented :-

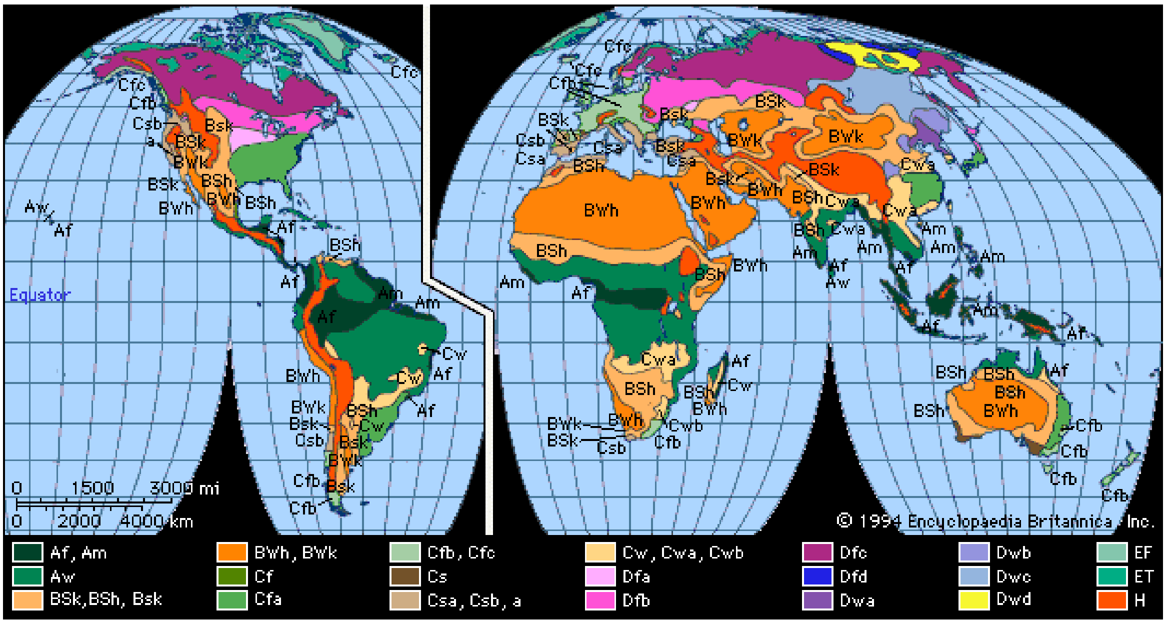

Figure D.1 *Geographical representation of Köppen climate zones*

The

- <u>Group of stations thereafter up to 1996:</u> **C:** Carpentras (Cs), Billings (Cfa), Tateno (Cfa), **D:** Regina (Dfb)

- <u>Group of stations thereafter up to1998:</u> **A:** Ilorin (Aw), **B:** Sede Boqer (BW), Alice Springs (BW), De Aar (BS), **C:** Florianopolis (Cwa), Lindenberg (Cfb), **D:** Toravere (Dfc), **E:** Syowa (EF)

- <u>Most recent stations:</u> **A:** SGP1 (Am), Manus (Aw), Nauru (Am), **B:** Tamanrasset (BW), Boulder SURFRAD (BS), Desert Rock (BW), **C:** Lauder (Cfa), Penn State (Cfa), Goodwin Creek (Cfb), **D:** Fort Peck (Dfb), Bondville (Dfb)

In total, the main groups were represented as follows:- A = 6, B = 7, C = 8, D = 4, E = 5. This is a fair distribution through the climate zones. Geographic as well as climatic representivity was therefore maintained in the BSRN network.

APPENDIX E

CONNECTION AND OPERATION OF A PYRGEOMETER

The setup and data reduction procedures of a pyrgeometer is more complex than that of a pyrheliometer or pyranometer. The author have amassed the following information in co-operation with several institutions and wishes to present it here as one concise unit. At the De Aar site, an Eppley PIR pyrgeometer was connected to a Campbell- Scientific CR10X–logger using dedicated PC208W software. The explanations in this appendix are therefore focused on those particular hardware and software types.

In this section, a circuit diagram of the PIR–to–logger connections and some explanations are offered. This is followed by expressions converting the measured quantities to data, and a complete Edlog programme (the user-programmable input for the datalogger) is presented.

E.1 CIRCUIT DIAGRAM

On the Eppley pyrgeometer, the input plug on the side have holes numbered A to H, which corresponds to pins on the matching plug numbered A to H. Pins A, B and C are used in connection to the thermopile (pin B, the battery compensation circuit connection, that was rejected by the BSRN community). D and E are the case (body) thermistor connections, F and G are the dome thermistor connections, and H is the earth (ground) connection.

On the logger, a Campbell Scientific CR10X, there are input terminals known as 1L, 1H, 2L, 2H, 3L and 3H. This represents differential signal input terminals, for channels 1, 2 and 3 respectively. The letters “L” and “H” represents lower and higher input channel connections. The “agnd” notation refers to an analogue ground connection (not the same as a power ground or Earth connection, and the terminals E1 and E2 are voltage-specific pulse excitation channels used in connection with the dome and body thermistors.

The pyrgeometer pins and logger terminals are connected in the way depicted in Figure E.1.

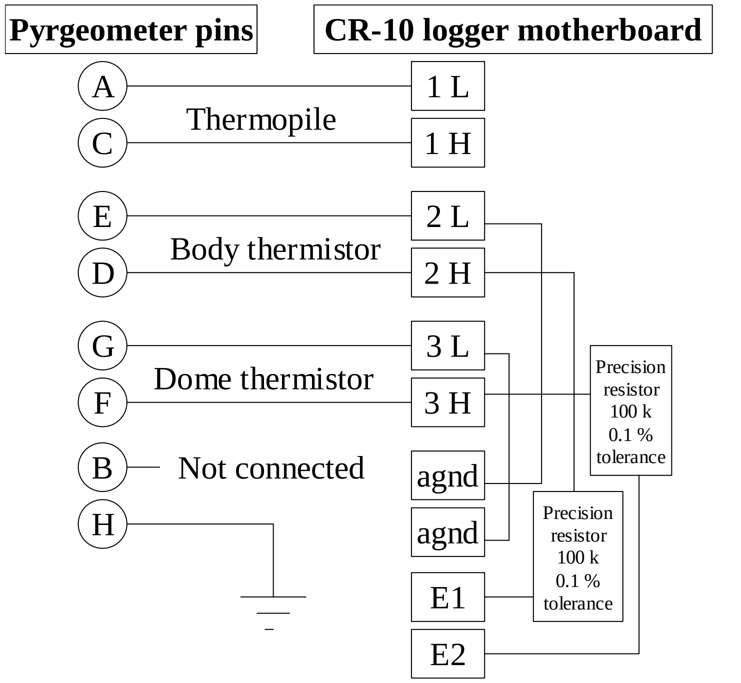

Figure E.1 *Circuit diagram for pyrgeometer-logger connections.*

Note: The precision resistors quoted here, are *not* ring-type resistors – it is very important that the resistors are of 0.1 % tolerance type and have negligible temperature dependence since their outputs are balanced against temperature-dependent devices (thermistors) used to measure the case and dome temperatures accurately.

E.2 EQUATIONS

The logger excites the differential channels 2H and 3H through the precision resistors R_v using excitation channels E1 and E2 with a precise voltage E_v for a specific period (typically 0.01s), at a preset frequency (100Hz). The voltage drops experienced at the ”agnd” terminals through the temperature–dependent thermistors are recorded at 2L and 3L as millivoltages V_b and V_d, dependent only on the case and dome temperatures.

Using Ohm's law and the definitions used in the previous paragraph for these circuits:

$$R_b = \frac{R_v V_b}{E_v - V_b}$$ for the body thermistor, and

$$R_d = \frac{R_v V_d}{E_v - V_d}$$ for the dome thermistor (E.1)

The resistance of the thermistors are used to convert to temperature using the Steinhart-Hart equation which is a least-squares fit for the YSI-44031 thermistors' table of dependence of temperature T to resistance R (Eplab, 1995).

$$T_b = \frac{1}{a + b\ln R_b + c\ln R_b{}^3}$$ for the body thermistor, and

$$T_d = \frac{1}{a + b\ln R_d + c\ln R_d{}^3}$$ for the dome thermistor (E.2)

where the regression constants a, b and c have the following values:-

a = 1.0295 E -03

b = 2.39 E -04

c = 1.568 E -07

Finally, temperature is converted to irradiance using the operational Albrecht and Cox (1977) expression, also featured in Section 3.1.3:

$$E_{LW} = \frac{p}{C_1} + \sigma T_b{}^4 + 3.5\sigma(T_b{}^4 - T_d{}^4)$$ (E.3)

E.3 EDLOG PROGRAMME

In the case of SW radiation, the very quantities direct, diffuse and global radiation, needed in the database, is directly sampled and measured. Therefore, the logger can be programmed to produce BSRN one-minute statistics (average, standard deviation, minimum and maximum). Since the individual 1Hz samples are not essential to produce the BSRN one-minute statistics, they are not stored and a minimal amount of logger space is consumed by SW radiation.

However, it is totally different with LW radiation, the irradiance values are *not* sampled as a quantity *per se.* Instead, only the directly measurable native quantities *pile, body* and *dome* can be sampled every second. Presenting one-minute statistics of *those* quantities, will not enable the scientist to calculate any LW irradiance quantities or statistics. Bear in mind that the said quantities will have to be treated using equations E.1, E.2 and E.3. The non-linearity of the last two equations implies that it does not make sense to use one-minute statistics of the native values to obtain one-minute statistics of the irradiance values.

There are two extreme options to address this problem.

(A) One extreme option is to store all the one-second samples of *pile, case* and *dome*, calculate the LW irradiance quantities in 1Hz resolution, and then produce accurate one-minute statistics. This option is unfeasible for De Aar, since there is simply not enough space on one logger, and data is in fact generated at a rate comparable to the speed of downloading it. If, therefore, a power failure or lightning strike temporarily breaks the connection between the logger and PC (such as on three previous occasions), data is lost almost immediately. This option was exercised on a trial basis in October 2001, but it soon proved unfeasible.

(B) The other extreme option is not to store any *pile, case* and *dome* samples. The logger is then programmed to calculate all LW irradiance and one-minute statistics internally. This uses the logger as a "black box" and it is unconditionally trusted to produce correct results. If, for any reason, LW irradiances look suspicious and re-calculation is required, it would not be possible if individual *pile, case* and *dome* samples are not available.

There solution is a compromise between (A) and (B). Samples must be stored, but how much ? It was found that a sampling period of 6 seconds produces 10 samples of *pile, case* and *dome* per minute, which still produces valid LWD values. The author developed a programme that performs LW irradiance calculations and one-minute statistics, and store 6-second samples. Since one program cycle takes about three to four seconds to repeat itself (i.e. do the complex calculations and record samples of the native quantities), one-second samples cannot be recorded in practice.

The complete Edlog programme code (original file SKY_PIR.CSI) is now presented here.

Take note: Three columns in newspaper-style per page.

```
;{CR10X}

; BSRN Datalogger program to sample LW constituents (pile,case,dome) and perform internal calculations of LWD in order to report a true avg, std, min and max per minute.  The samples are done every second and reported every 6 sec in order to redo calculations if internal calc of LWD fails.
;
; D.J. Esterhuyse, 16 October 2002.

; Program 1 samples Pile/Case/Dome

; Program 2 calculates LW irradiance avg, std, min, max.



*Table 1 Program
  01: 1          Execution Interval (seconds)

1:  Ex-Del-Diff (P8)
 1: 1        Reps
 2: 15       2500 mV Fast Range
 3: 2        DIFF Channel
 4: 1        Excite all reps w/Exchan 1
 5: 10       Delay (units 0.01 sec)
 6: 2000     mV Excitation
 7: 1        Loc [ Case     ]
 8: 1.0      Mult
 9: 0.0      Offset

2:  Ex-Del-Diff (P8)
 1: 1        Reps
 2: 15       2500 mV Fast Range
 3: 3        DIFF Channel
 4: 2        Excite all reps w/Exchan 2
 5: 10       Delay (units 0.01 sec)
 6: 2000     mV Excitation
 7: 2        Loc [ Dome     ]
 8: 1.0      Mult
 9: 0.0      Offset

3:  Volt (Diff) (P2)
 1: 1        Reps
 2: 2        7.5 mV Slow Range
 3: 1        DIFF Channel
 4: 3        Loc [ Pile     ]
 5: 1.0      Mult
 6: 0.0      Offset

4:  Batt Voltage (P10)
 1: 4        Loc [ BatV     ]

5:  Internal Temperature (P17)
 1: 5        Loc [ IntT     ]

6:  If time is (P92)
 1: 0        -- Minutes (Seconds --) into a
 2: 6        Interval (same units as above)
 3: 10       Set Output Flag High (Flag 0)

7:  Real Time (P77)
 1: 1121     (Same as 1221) Y,D,Hr/Mn,Sec

8:  Resolution (P78)
 1: 01       High Resolution

9:  Average (P71)
 1: 1        Reps
 2: 3        Loc [ Pile     ]

10:  Average (P71)
 1: 1        Reps
 2: 1        Loc [ Case     ]

11:  Average (P71)
 1: 1        Reps
 2: 2        Loc [ Dome     ]

12:  Serial Out (P96)
 1: 71       SM192/SM716/CSM1

; Program 1 samples Pile / Case / Dome

; Program 2 calculates LW irradiance avg, std, min, max.


*Table 2 Program
  02: 4          Execution Interval (seconds)

; CALCULATION PHASE of LW irradiance avg, min, max and std.

; Stefan-Bolzmann constant Sigma defined:
1:  Z=F (P30)
 1: 5.67     F
 2: -8       Exponent of 10
```

3: 25 Z Loc [Sigma]

; TERM 1 = Pile irradiance - 1/0.00427 = 234.192
2: Z=X*F (P37)
1: 3 X Loc [Pile]
2: 234.192 F
3: 7 Z Loc [TERM_1]

; For calculations: different signs of hundred thousand:
; Minus hundred thousand:-
3: Z=F (P30)
1: -1 F
2: 5 Exponent of 10
3: 23 Z Loc [Min_Hu_th]

; Plus hundred thousand:-
4: Z=F (P30)
1: 1 F
2: 5 Exponent of 10
3: 9 Z Loc [Hund_thou]

; Resistances of case and dome:-

5: Z=X*Y (P36)
1: 1 X Loc [Case]
2: 23 Y Loc [Min_Hu_th]
3: 8 Z Loc [R_c_upper]

6: Z=X+F (P34)
1: 1 X Loc [Case]
2: -2000 F
3: 13 Z Loc [R_c_lower]

7: Z=X/Y (P38)
1: 8 X Loc [R_c_upper]
2: 13 Y Loc [R_c_lower]
3: 10 Z Loc [R_case]

8: Z=X*Y (P36)
1: 2 X Loc [Dome]
2: 23 Y Loc [Min_Hu_th]
3: 14 Z Loc [R_d_upper]

9: Z=X+F (P34)
1: 2 X Loc [Dome]
2: -2000 F
3: 15 Z Loc [R_d_lower]

10: Z=X/Y (P38)
1: 14 X Loc [R_d_upper]
2: 15 Y Loc [R_d_lower]
3: 16 Z Loc [R_dome]

; TEMPERATURES of case and dome

11: Z=LN(X) (P40)
1: 10 X Loc [R_case]
2: 24 Z Loc [ln_R_case]

; Polynomial pre-scaled with 10^5 to enable coefficient entry.
12: Polynomial (P55)
1: 1 Reps
2: 24 X Loc [ln_R_case]
3: 22 F(X) Loc [Poly_T_cx]
4: 102.95 C0
5: 23.91 C1
6: 0.0 C2
7: 0.01568 C3
8: 0.0 C4
9: 0.0 C5

; and apply de-pre-scaling to polynomial:-

13: Z=X/Y (P38)
1: 22 X Loc [Poly_T_cx]
2: 9 Y Loc [Hund_thou]
3: 20 Z Loc [Poly_T_c]

14: Z=1/X (P42)
1: 20 X Loc [Poly_T_c]
2: 18 Z Loc [T_case]

15: Z=LN(X) (P40)
1: 16 X Loc [R_dome]
2: 26 Z Loc [ln_R_dome]

; Polynomial pre-scaled with 10^5 to enable coefficient entry.
16: Polynomial (P55)
1: 1 Reps
2: 26 X Loc [ln_R_dome]
3: 27 F(X) Loc [Poly_T_dx]
4: 102.95 C0
5: 23.91 C1
6: 0.0 C2
7: 0.01568 C3
8: 0.0 C4
9: 0.0 C5

; and apply de-pre-scaling to polynomial:-

17: Z=X/Y (P38)
1: 27 X Loc [Poly_T_dx]
2: 9 Y Loc [Hund_thou]
3: 21 Z Loc [Poly_T_d]

18: Z=1/X (P42)
1: 21 X Loc [Poly_T_d]
2: 19 Z Loc [T_dome]

; TERM_2 calculation

19: Z=F (P30)
1: 4 F
2: 0 Exponent of 10
3: 28 Z Loc [Four]

20: Z=X^Y (P47)
1: 18 X Loc [T_case]
2: 28 Y Loc [Four]
3: 29 Z Loc [T_c_four]

21: Z=X*Y (P36)
 1: 25 X Loc [Sigma]
 2: 29 Y Loc [T_c_four]
 3: 30 Z Loc [TERM_2]

; TERM_3 calculation

22: Z=X^Y (P47)
 1: 19 X Loc [T_dome]
 2: 28 Y Loc [Four]
 3: 31 Z Loc [T_d_four]

23: Z=X-Y (P35)
 1: 29 X Loc [T_c_four]
 2: 31 Y Loc [T_d_four]
 3: 32 Z Loc [Bracket]

24: Z=X*F (P37)
 1: 25 X Loc [Sigma]
 2: 3.5 F
 3: 33 Z Loc [Bracket_2]

25: Z=X*Y (P36)
 1: 32 X Loc [Bracket]
 2: 33 Y Loc [Bracket_2]
 3: 34 Z Loc [TERM_3]

; LW Irradiance calculation

26: Z=X+Y (P33)
 1: 30 X Loc [TERM_2]
 2: 34 Y Loc [TERM_3]
 3: 35 Z Loc [tempterms]

27: Z=X+Y (P33)
 1: 35 X Loc [tempterms]
 2: 7 Y Loc [TERM_1]
 3: 36 Z Loc [LW_IRR]

; OUTPUT PHASE of LW irradiance avg, min, max and std.

28: If time is (P92)
 1: 0 Minutes (Seconds --) into a
 2: 1 Interval (same units as above)
 3: 10 Set Output Flag High (Flag 0)

29: Real Time (P77)
 1: 1120 (Same as 1220) Y,D,Hr/Mn

30: Resolution (P78)
 1: 01 High Resolution

31: Average (P71)
 1: 1 Reps
 2: 36 Loc [LW_IRR]

32: Standard Deviation (P82)
 1: 1 Reps
 2: 36 Sample Loc [LW_IRR]

33: Minimize (P74)
 1: 1 Reps
 2: 00 Time Option
 3: 36 Loc [LW_IRR]

34: Maximize (P73)
 1: 1 Reps
 2: 00 Time Option
 3: 36 Loc [LW_IRR]

35: Sample (P70)
 1: 1 Reps
 2: 7 Loc [TERM_1]

36: Sample (P70)
 1: 1 Reps
 2: 30 Loc [TERM_2]

37: Sample (P70)
 1: 1 Reps
 2: 34 Loc [TERM_3]

*Table 3 Subroutines

End Program

-Input Locations-
1 Case 1 3 1
2 Dome 1 3 1
3 Pile 1 2 1
4 BatV 1 0 1
5 IntT 1 0 1
6 Pile_cal 1 0 0
7 TERM_1 1 2 1
8 R_c_upper 1 1 1
9 Hund_thou 1 2 1
10 R_case 1 1 1
11 R_lower 1 0 0
12 R_upper 1 0 0
13 R_c_lower 1 1 1
14 R_d_upper 1 1 1
15 R_d_lower 1 1 1
16 R_dome 1 1 1
17 R_d_uppe 1 0 0
18 T_case 1 1 1
19 T_dome 1 1 1
20 Poly_T_c 1 1 1
21 Poly_T_d 1 1 1
22 Poly_T_cx 1 1 1
23 Min_Hu_th 1 2 1
24 ln_R_case 1 1 1
25 Sigma 1 2 1
26 ln_R_dome 1 1 1
27 Poly_T_dx 1 1 1
28 Four 1 2 1
333 _________ 1 0 0
29 T_c_four 1 2 1
30 TERM_2 1 2 1
31 T_d_four 1 1 1
32 Bracket 1 1 1
33 Bracket_2 1 1 1
34 TERM_3 1 2 1
35 tempterms 1 1 1
36 LW_IRR 1 4 1
-Program Security-
0000
0000
0000
-Mode 4-
-Final Storage Area 2-
0
-CR10X ID-
0
-CR10X Power Up-
3